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ASME Pressure Vessel Code for Nuclear Transport and Storage

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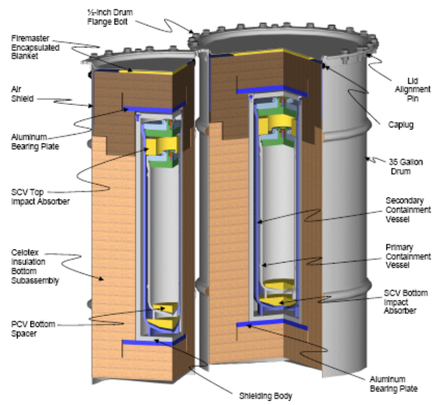
ABSTRACT

The U.S. Department of Energy Packaging Certification Program, Office of Packaging and Transportation, Office of Environmental Management sponsors a training course on the application of the ASME Boiler and Pressure Vessel Code (ASME Code) to radioactive material transportation packaging, which has been conducted annually by Argonne National Laboratory since the early 2000s. The course was significantly expanded in 2013, from three to five days, to include the application of the ASME Code to storage casks for spent nuclear fuel and high-level radioactive waste. In 2015, the ASME Code course became part of the curriculum of the Graduate Certificate in Nuclear Packaging (GCNP) program at the University of Nevada, Reno. The purpose of this course is to provide guidance for the application of the ASME Code to Type B radioactive and fissile material transportation packagings and spent nuclear fuel storage casks, and to facilitate the design, fabrication, examination, and testing of packagings and casks. Both regulatory requirements in Title 10, Code of Federal Regulations, Parts 71 and 72, and the ASME Code requirements for transportation packagings and storage casks are addressed, with emphasis on Section III Division 3 of the ASME Code, *Containments for Transportation and Storage of Spent Nuclear Fuel and High Level Radioactive Material and Waste*; also discussed are Section II, Section III Division 1, Section V, Section VIII Division 1, and Sections IX and XI. Among the specific topics covered are the application of the Code requirements to structural materials, containments, loading and design, fabrication, welding, examination, testing requirements, quality assurance, aging management for long-term storage of spent fuel, transportation, and inspection and monitoring technologies. The ASME Code course is one of the three required courses for the GCNP program, the educational objectives of which are to provide the applied knowledge and skills required by mechanical, materials, and nuclear engineers to be successful as nuclear packaging designers, analysts, and users. Over 50 students have enrolled in the GCNP courses since 2015; the first GCNP Certificate was awarded in 2017. This paper will provide highlights of the ASME Code course, including lessons learned through feedback received from the course participants, and future directions.

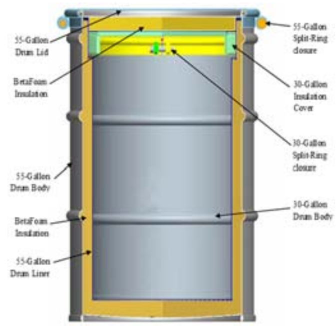
INTRODUCTION

The U.S. Department of Energy (DOE) Packaging Certification Program (PCP), Office of Packaging and Transportation, is the certifying authority for packagings constructed by or under the direction of the DOE for transportation of radioactive and fissile materials [1, 2]. Beginning in the mid-1980s, DOE/PCP has sponsored a suite of training courses to enhance the safety and security of nuclear and other radioactive materials during transport and storage, including aging management and advanced surveillance for extended storage and subsequent transportation of spent nuclear fuel and high-level waste. Among the DOE PCP courses, four (4) were developed and have been offered by Argonne National Laboratory (Argonne): (1) ASME Pressure Vessel Code for Nuclear Transport and Storage; (2) Quality Assurance for Radioactive Material Packaging; (3) Security of Nuclear and Other Radioactive Materials during Transport (for both domestic and international transportation); and (4) ARG-US Remote Monitoring Systems Technology.

Transportation packagings of high-level radioactive materials must maintain their primary safety functions of containment of radioactivity, shielding for radiation, and nuclear subcriticality during normal conditions of transport and hypothetical accident conditions specified in Title 10, Code of Federal Regulations, Part 71 (10CFR71), *Packaging and Transportation of Radioactive Material* [3]. Figure 1 shows selected examples of DOE PCP-certified Type B and fissile material transportation packagings.



(a)



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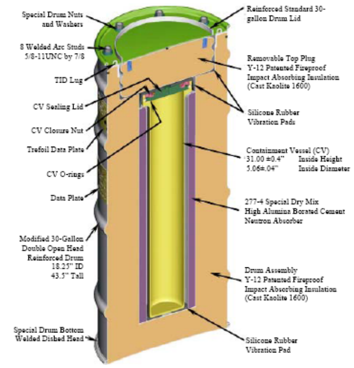

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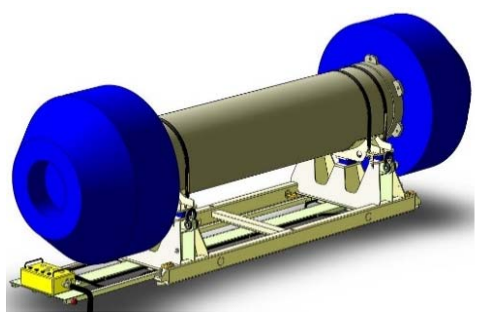

(d)

(e)

Figure 1. Selected DOE/PCP-certified transportation packagings for radioactive and fissile materials: (a) 9975 Type B(M)F Packaging, (b) 9979 Type AF Packaging, (c) ES-3100 Type B(U)F Packaging, (d) Hanford Unirradiated Fuel Package, and (e) NAC International Legal Weight Truck (LWT).

For spent nuclear fuel, dry cask storage systems (DCSSs), such as those shown in Figure 2 at three Independent Spent Fuel Storage Installations (ISFSIs), are required to prevent release of radioactive materials, avoid excessive external radiation levels, provide heat dissipation by passive cooling, maintain subcriticality, and provide for ready retrieval of contents when necessary [4].

(a)

(b)

(c)

Figure 2. Spent-fuel DCSSs on ISFSIs at (a) San Onofre, (b) Diablo Canyon, and (c) North Anna.

Title 10, Code of Federal Regulations, Part 72 (10 CFR 72), *Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste,* stipulates the regulatory safety requirements for DCSSs containing spent nuclear fuel and high-level radioactive waste [4]. The regulations in 10 CFR 71 and 10 CFR 72 do not establish design standards and acceptance criteria that can be used for the design and evaluation of the structural integrity of transportation packagings and storage casks for radioactive materials and spent nuclear fuel. The ASME Boiler and Pressure Vessel Code (ASME Code) establishes rules of safety for the design, fabrication, examination, and testing of boilers, pressure vessels, nuclear power plant components, and transportation packagings and storage casks for radioactive materials. It is a preeminent pressure vessel code and is accepted in the United States and by many other countries. For specific application to packagings and casks used for transportation and storage, the ASME Code is generally acceptable to DOE [5] and NRC with respect to material selection, design, welding, examination, and inspection. The NRC endorses the use of the ASME Code Sections and revisions in regulatory guides [6] and NRC Standard Review Plans [7–11].

Depending on the level of radioactivity of the contents being transported in the packaging and the safety function of the packaging's components, different ASME Code Sections, Divisions and Subsections are used for the design and fabrication of metal containments for the packagings and casks. Table 1 below shows the selection of applicable ASME Code Sections based on Component Safety Groups. For Category I Containment, Section III Division 1, Subsection NB contains rules for the design of nuclear power plant components, whereas Division 3, Subsections WB and WC contain rules for the design of containment systems, respectively, for transportation and storage of spent fuel and high-level waste. Portions of the ASME Code Section III that use a "design-by-analysis" approach for Class 1 components have been adapted in NRC Regulatory Guide (RG) 7.6 as acceptable design criteria for transportation packaging and shipping cask containment vessels. The design criteria for normal transport conditions, as defined in 10CFR71, are similar to the criteria for Level A Service Limits of Section III of the ASME Code. The design criteria for off-normal (storage only) conditions are similar to those for Level C Service Limits, and the design criteria for accident conditions are similar to those for Level D Service Limits in Section III of the ASME Code.

Table 1. Selection of Applicable ASME Code Sections Based on Component Safety Groups[a]

Increasing Radioactivity →

Components Safety Group	Container Contents		
	Category III	Category II	Category I
Containment	Section VIII Division 1	Section III Division 1, Subsection ND	Section III Division 1, Subsection NB, or Division 3, Subsection WB/WC[b]
Criticality	Section III Division 1, Subsection NG		
Other Safety	Section VIII Division 1 or Section III Division 1, Subsection NF		

[a] Adapted from NRC Regulatory Guide 7.11 and NUREG/CR-3854 [12].
[b] The applicable ASME Code Sections for storage containment are Section III, Division 1 or 3, Subsections NB/WC

The NRC and DOE initially recommended the use of Section III Division 1 of the ASME Code for radioactive materials transportation packagings in 1978, because it was the only available authoritative guidance for structures and components that are similar to nuclear power plant components. Since then, Section III Division 3 of the ASME Code has been developed specifically for radioactive materials containment systems for transportation packagings and storage casks. Endorsement of Section III Division 3 of the ASME Code by NRC is pending.

THE COURSE LEARNING OBJECTIVE

The objective of the ASME Code course is to facilitate the design, fabrication, examination, and testing of radioactive-material transportation packagings and dry storage casks for spent nuclear fuel that meet all applicable ASME Code requirements and federal regulations. The course also addresses aging management programs and inspection and monitoring of storage casks. Because the course provides insight into the DOE and NRC certification processes for transportation packagings and storage casks, students will gain knowledge and better understanding of the following:

i) Federal regulations that govern transportation packaging for radioactive material and DCSSs for spent nuclear fuel;
ii) NRC guidance documents, including regulatory guides and NUREG reports (e.g., Standard Review Plans), and DOE Orders and Review Guides;
iii) General background and structure of the ASME Code, with emphasis on ASME Code Section III Division 3, *Containments for Transportation and Storage of Spent Nuclear Fuel and High Level Radioactive Material and Waste*, and discussion of Section III Division 1; Section VIII Division 1; and Sections II, IX, and XI;
iv) Code and non-Code materials, containment loadings, and design considerations with emphasis on design-by-analysis rules, design of internal support structures, and design of bolting closures;
v) Fabrication, welding, examination, testing requirements, and quality assurance of transportation packagings and storage casks; design qualification by physical testing; and leak-rate testing for containment and confinement;
vi) Analysis considerations for evaluations of structural, thermal, containment/confinement, radiation shielding and criticality safety performance of packagings and casks;
vii) Computer modeling, simulation (CMS), verification and validation (V&V);
viii) Aging management programs for long-term storage and subsequent transportation of spent fuel; and
ix) Inspection and monitoring technologies.

Figure 3 shows the flowchart of the course. In addition to the lectures and discussions, other course activities include in-class exercises, homework assignments, facility tours, and a final exam. This is a classroom course, designed with particular emphasis on understanding the regulatory basis, current design practice, and engineering rationale for applying the ASME Code to packaging for transportation of radioactive materials and DCSSs for spent nuclear fuel.

LESSONS LEARNEAD AND FUTURE COURSES

The ASME Code courses have been held at Argonne annually since 2014, which was also the year with the largest number of participants (27) so far from government agencies, industry, national labs, universities, Canada, and the Republic of Korea [13]. Using participant feedback and lessons learned from these courses, the agenda was re-designed to enhance class interactions and include topics that are of interest to extended long-term storage of spent nuclear fuel and high-level waste, such as vacuum drying of spent fuel, hydride reorientation and embrittlement of high-burnup PWR fuel, aging management programs and time-limited aging analysis, and monitoring and inspection of DCSSs during extended long-term storage and subsequent transportation of spent fuel [14].

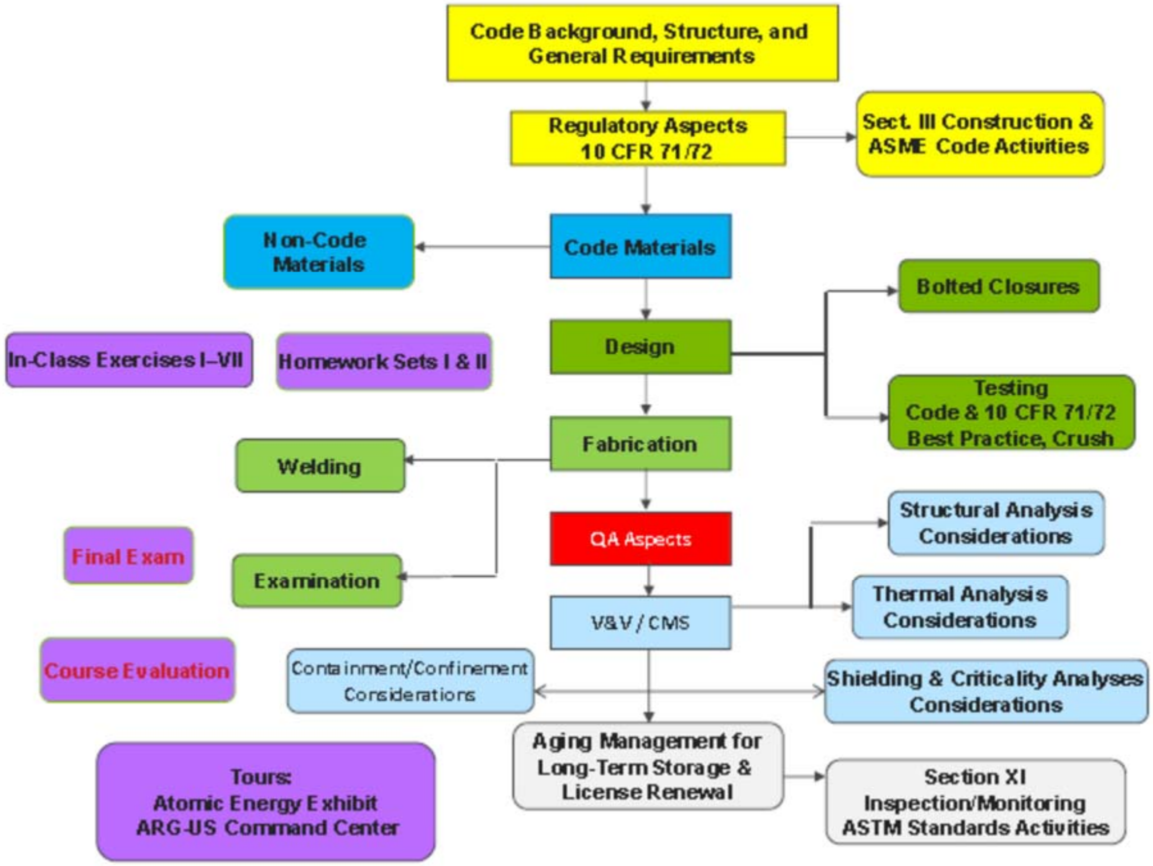

Figure 3. Flowchart of the ASME Code course

The University of Nevada-Reno's (UNR's) Graduate Certificate in Nuclear Packaging (GCNP) program has also matured over the last few years, with additions of new electives that broaden the scope while adding depth to the program [15]. The ongoing efforts related to the GCNP include improving program administration; establishing an advisory council; developing new elective courses; publicizing the GCNP to potential students and their employers; and offering a 2019 International Summer School at UNR that combines the ASME Code for Nuclear Transport and Storage and the Quality Assurance for Radioactive Material Packaging courses in two consecutive weeks (June 3–7 and June 10–14). We also conducted a workshop entitled "The Application of the ASME Code and QA Principles to Packaging and Casks for Transportation and Storage of Radioactive Materials, Spent Nuclear Fuel and High-Level Waste" at the 2019 WM Symposia in Phoenix, Arizona, on March 3, 2019. This workshop highlighted the contents of the ASME Code and QA courses for sixteen domestic and international WM attendees.

ACKNOWLEDGMENTS

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